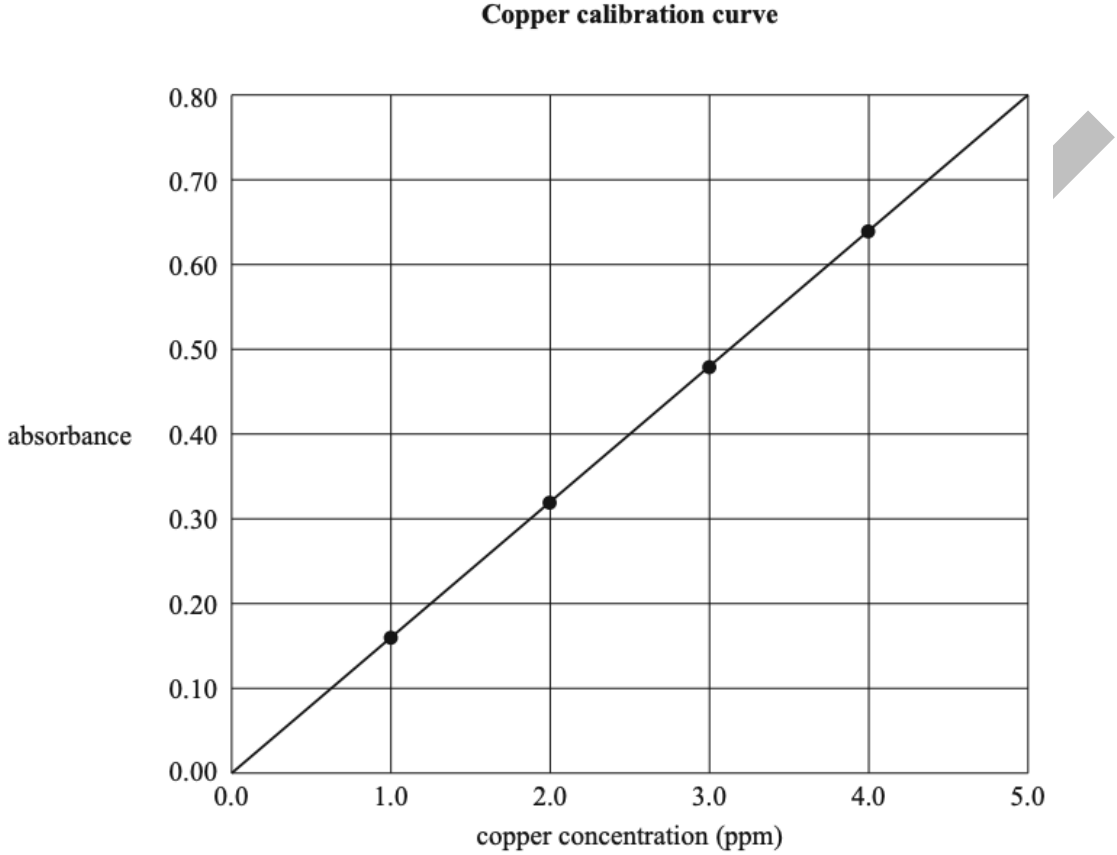
Section I – Analysis of Inorganic Compounds

Use the following information to answer Questions 16 and 17
An atomic absorption spectrometer can be used to determine the level of copper in soils. The calibration curve below plots the absorbance of four standard copper solutions against the concentration of copper ions in ppm.

The concentrations of copper ions in the standard solutions were 1.0, 2.0, 3.0 and 4.0 mg L^{-1}. (1 mg L^{-1} = 1 ppm)



1. **VCE 2019 Q16**
The concentration of copper in a test solution can be determined most accurately from the calibration curve if it is between

A. 0.0 ppm and 5.0 ppm.
B. 0.0 ppm and 4.0 ppm.
C. 1.0 ppm and 4.0 ppm.
D. 1.0 ppm and 5.0 ppm.

Explanation:
Only concentration and absorbance between the first and last data point of the calibration curve can be determined accurately.

2. **VCE 2019 Q17**
If the test solution gave an absorbance reading of 0.40, what would be the concentration of copper ions in the solution in mol L^{-1}?

A. 2.5
B. 3.9×10^{-2}
C. 3.9×10^{-5}
D. 2.5×10^{-6}

Explanation:
From calibration curve, 0.40 = 2.5 mg/L of Cu^{2+}. This equals to 0.0025 g/L = 0.0025/63.55 (molar mass of copper) = 3.9×10^{-5} mol/L

3. **VCE 2013 Q8**
A forensic chemist tests mud from a crime scene to determine whether the mud contains zinc.

Which one of the following analytical techniques would be best suited to this task?

A. infrared spectroscopy
B. mass spectrometry
C. atomic absorption spectroscopy
D. nuclear magnetic resonance spectroscopy

Explanation:
AAS is used to determine concentration of metal or metal ions. It is highly accurate and specific to a particular type of metal e.g. zinc.

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4. **VCE 2011 Q20**

The amount of copper in a solution of copper(II) sulfate can be determined using atomic absorption spectroscopy.

When a blue copper(II) sulfate solution is introduced into an atomic absorption spectrometer, a green flame is observed.

Consider the following statements

I. A copper (II) sulfate solution appears blue because it absorbs red light.
II. The metal species undergoes oxidation in the flame.
III. The flame is green due to electron transitions from a higher energy state to a lower energy state.

Which of the above statements are true?

A. I only
B. I and III only
C. II and III only
D. I, II and III

Explanation:

Blue compounds absorb red light strongly (refer to colour wheel). In the flame test, electrons in metal atoms are excited to a higher state (absorption), followed by their return to the ground state and release of energy in the form of visible light. The flame test for copper is green (blue/green) because the visible light released is green. Metal species are not oxidised in the flame test.

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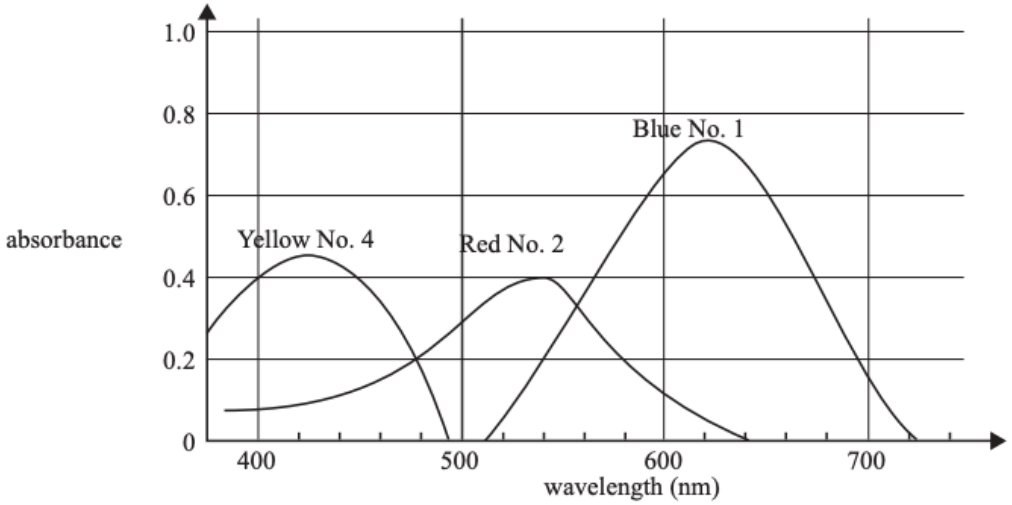
5. **VCE 2010 Q9**

The graph shows the absorption spectra of three food dyes: Blue No. 1, Red No. 2 and Yellow No. 4.



Which one of the following is the best wavelength to determine the concentration of Red No. 2 dye in a solution containing a mixture of all three dyes?

A. 430 nm
B. 500 nm
C. 540 nm
D. 620 nm

Explanation:

The best wavelength to use is one where Red No. 2 dye absorbs strongly but no other dye in the mixture does, i.e. 500 nm. According to the absorption spectra provided, Red No. 2 absorbs most strongly at 540 nm. However, because Blue No.1 dye also absorbs significantly at 540 nm, it is not the best wavelength to use. Students who chose option B may have focused solely on the maximum absorption of Red No. 2 dye.

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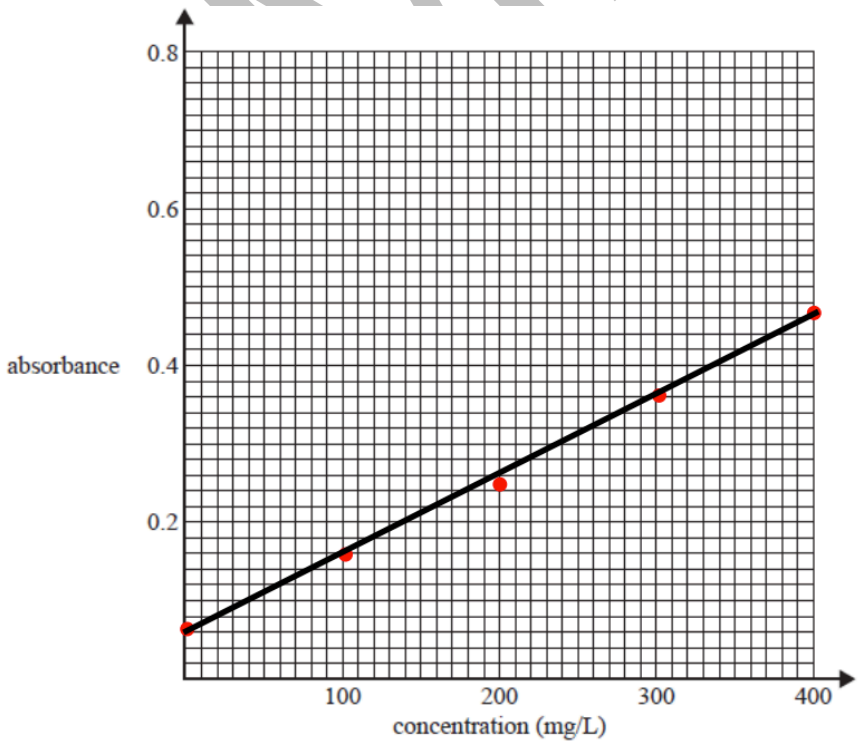
VCE 2012 Question 6 (7 marks)
The iron content in multivitamin tablets was determined using atomic absorption spectroscopy.
The absorbances of four standards were measured.
Three multivitamin tablets were selected. Each tablet was dissolved in 100.0 mL of water. The absorbance of each of the three solutions was then measured.
The following absorbances were obtained.

Solution	Concentration mg/L	Absorbance
Standard 1	0.00	0.06
Standard 2	100.0	0.16
Standard 3	200.0	0.25
Standard 4	300.0	0.36
Standard 5	400.0	0.46
Tablet 1	–	0.39
Tablet 2	–	0.42
Tablet 3	–	0.45

(a)

(i) Use the grid below to construct a calibration graph of the absorbances of the standard solutions. **2**



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VCE 2012 Question 6 (continued)

(ii) Determine the average iron content, in milligrams, of the multivitamin tablets. **2**

Average absorbance of the iron tables = 0.42

c(Fe) = 360 mg L^{-1}

Average m(Fe) in each tablet (in 100 mL solution) = 36 mg

Spectroscopic techniques work on the principle that, under certain conditions, atoms, molecules or ions will interact with electromagnetic radiation. The type of interaction depends on the wavelength of the electromagnetic radiation.

(b) Name one spectroscopic technique that you have studied this year.

(i) Which part of the electromagnetic spectrum does this technique use? **1**

(ii) How does this part of the electromagnetic spectrum interact with matter? What information does this spectroscopic technique provide? **2**

Spectroscopic technique	Part of spectrum	How it interacts	Information provided
AAS (Atomic Absorption)	visible radiation	Electrons (in atoms) move to higher energy levels	Concentration of the absorbing species
UV-visible	ultraviolet and/or visible radiation	Electrons (in molecules or ions) move to higher energy levels	Concentration of the absorbing species
IR (infrared)	infrared radiation	'Change' in bond vibration/ stretching/polarity in molecules	Types of bonds/functional groups in a molecule
1H NMR (Nuclear magnetic resonance)	radiowave radiation	1H nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of H atoms in a molecule
13C NMR (Nuclear magnetic resonance)	radiowave radiation	13C nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of C atoms in a molecule

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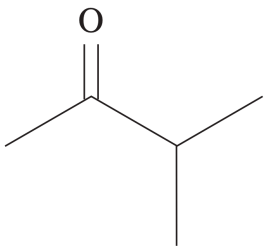
Section II – Analysis of Organic Compounds

1. **VCE 2019 Q3**
A compound has the following skeletal formula



The compound is analysed using mass spectrometry.

The molecular ion peak of the compound is at

A. m/z = 71
B. m/z = 74
C. m/z = 85
D. m/z = 86

Explanation:
The molar mass of this compound is 86.0 g mol^{-1} so a molecular ion (parental ion) peak will be present at m/z = 86

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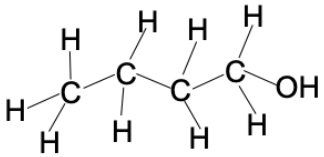
2. **VCE 2019 Q27**

An organic compound has a molar mass of 88 g mol^{-1}. The ^{13}C NMR spectrum of the organic compound shows four distinct peaks.
The organic compound is most likely

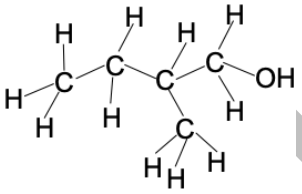
A. butan-1-ol.
B. 2-methyl-butan-1-ol.
C. 2-methyl-butan-2-ol.
D. 2,2-dimethyl-propan-1-ol.

Explanation:

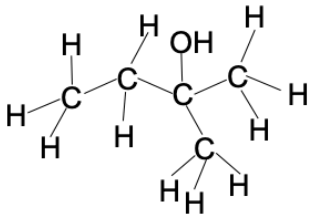
A. 4 carbon environments



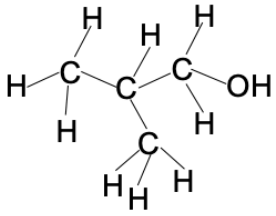
B. 5 carbon environments



C. 4 carbon environments



D. 3 carbon environments



Both butan-1-ol ($C_4H_{10}O$) and 2-methylbutan-2-ol ($C_5H_{12}O$) will show four distinct peaks on their ^{13}C NMR spectra.

$M(C_4H_{10}O) = 74.0$ g mol^{-1}
$M(C_5H_{12}O) = 88.0$ g mol^{-1}

3. **VCE 2019 NHT Q10**

A researcher uses a combination of spectroscopic techniques to determine the structure of a molecule. Which combination of spectroscopic techniques provides the most information about the molecule's functional groups and number of carbon environments?

A.	Mass spectrometry	^{13}C NMR
B.	Infrared	^{13}C NMR
C.	Infrared	Mass spectrometry
D.	Mass spectrometry	^{1}H NMR

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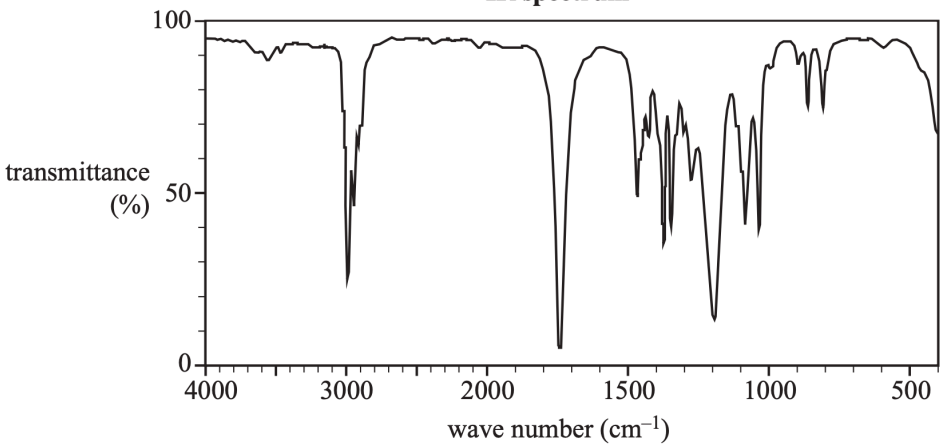
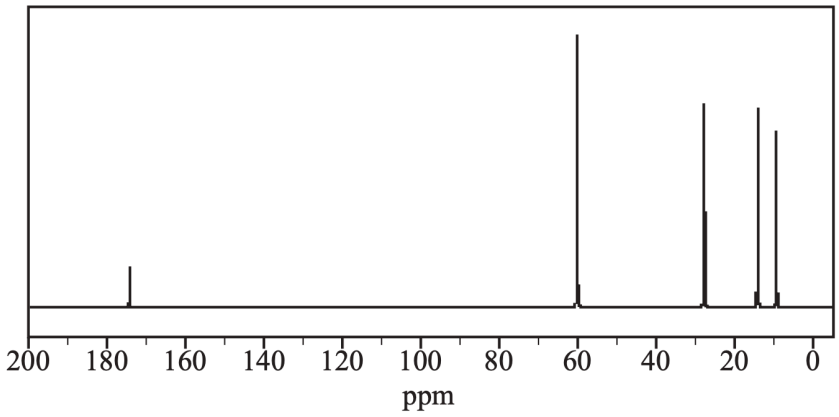
VCE 2017 NHT Q3 (6 marks)

A compound has the molecular formula $C_5H_{10}O_2$. It is analysed by infrared (IR), ^{13}C NMR and ^{1}H NMR spectroscopy. The resulting spectra are shown below.

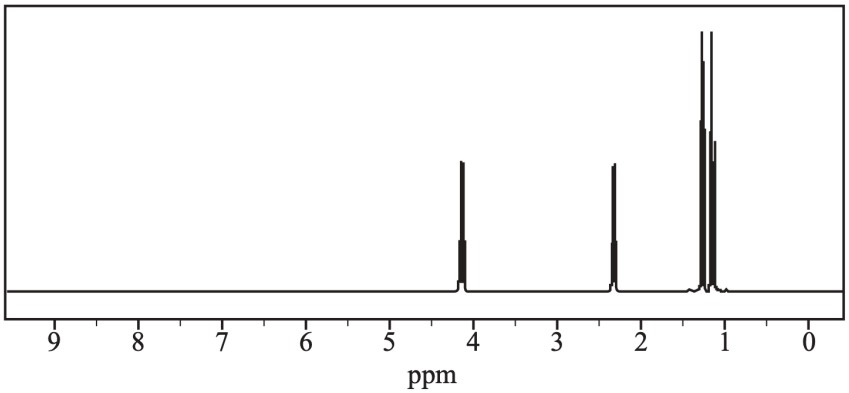
IR spectrum



^{13}C NMR spectrum



^{1}H NMR spectrum



Data: SDBS Web, http://sdbs.db.aist.go.jp,
National Institute of Advanced Industrial Science and Technology

VCE 2017 NHT Q3 (continued)

Information for the splitting pattern of the ^{1}H NMR spectrum is shown below

Chemical shift	Relative peak area	Splitting pattern
4.1	2	4 peaks
2.3	2	4 peaks
1.3	3	3 peaks
1.1	3	3 peaks

(a) Using the IR spectrum provided, identify a bond in a molecule of $C_5H_{10}O_2$ and give its wave number. **1**

C=O, 1750 cm^{-1} (1680–1750 cm^{-1})
or
C–H, 3000 cm^{-1} (2850–3300 cm^{-1})

(b) Using the ^{1}H NMR spectrum provided, state the number of hydrogen environments in a molecule of $C_5H_{10}O_2$. **1**

Four

(c) What specific information about the structure of a molecule of $C_5H_{10}O_2$ is provided by the splitting pattern in the ^{1}H NMR spectrum? **1**

The molecule contains 2 CH_3CH_2– groups.

- The splitting patterns (3 peaks) at δ = 1.1 ppm and δ = 1.3 ppm both suggest two instances of the presence of 2 H atoms on a neighbouring C atom.
- The splitting patterns (4 peaks) at δ = 2.3 and δ = 4.1 both suggest two instances of the presence of 3 H atoms on a neighbouring C atom.

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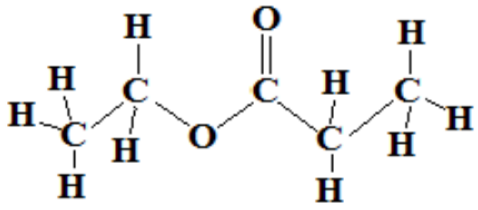
(d) Draw a structure consistent with the data provided for a molecule of $C_5H_{10}O_2$. Explain how the structure you have drawn is supported by evidence from the ^{13}C NMR spectrum, which contains five peaks. **3**



The ^{13}C NMR spectrum shows five peaks consistent with the five different C environments shown in the structure.

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